SLAC – PUB – 3975
May 1986
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COLLECTOR MATERIAL DESORPTION TESTS*

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1. Summary

To obtain long cathode lifetimes, the surface of the spent beam collector for the photocathode RF power source (called the Lasertron) must have a low coefficient of desorption of gas molecules by electrons. We assembled a low voltage ($\leq$ 10 kV) ultrahigh vacuum electron gun and target system to measure the desorption rates of CO and CO_2 under conditions where the power density, charge density and pressure were the same order as expected in the lasertron. Copper coated with a thin layer of a nonevaporable getter (NEG) was found to have a coefficient of desorption of CO_2 (CO) at least 30 (5) times less than vacuum degassed high grade OFHC copper. The NEG material may be coated on the usual collector geometries and therefore can substantially reduce operating tube pressure in conventional klystron and other high current tubes.

2. Introduction

SLAC has a program under way to study the use of photoemission cathodes as sources of bunched electron beams for high power microwave generation, the so-called "Lasertron." While photoemission cathodes offer the advantages of very high current density operation and straightforward temporal (or spatial) modulation at high frequencies, they are more susceptible to residual gas poisoning than thermionic cathodes. Thus, for successful photocathode use in a high power microwave device, there is a premium on limiting the sources of residual gas during operation.

One very major source of such gas is electron induced desorption from the spent beam collector. It was suggested to us that a collector surface of nonevaporable getter (NEG) material might offer substantially reduced gas desorption.[1] To test this suggestion, and to evaluate candidate collector materials in general, we constructed a small UHV system to measure electron induced desorption from small area samples. The operating conditions were chosen to approximate the actual operating conditions of the spent beam collector of the SLAC proof-of-principle Lasertron.[2] For the photocathode planned for this device, CO and CO_2 have been shown to be the most harmful of the residual gases typically present, so our measurements have concentrated on these gases. Our results indicate that a thin layer of NEG material on OFHC copper gives a significantly smaller desorption than the best vacuum degassed OFHC copper samples we evaluated.

3. Apparatus

The UHV system assembled for these measurements employed a plane, 6 mm square tungsten ribbon filament as a thermionic emitter. The filament was located within, and electrically isolated from, a stainless steel tube. Application of a low voltage between the filament and the stainless tube was adequate to turn the beam current on and off.

The sample to be evaluated, 25 mm in diameter, was brazed into the end of a stainless tube which was in turn mounted in a conflat flange. The sample was electrically isolated by a ceramic insulator able to hold off over 50 kV, though such high voltages were not used in these tests. During operation of the system, the sample was cooled by a flow of LCW water introduced into the stainless tube. Activation of the NEG material on the surface of the sample was done by heating with a flow of heated liquid nitrogen boiloff gas into this same tube. Typical activation temperatures for the NEG material used were 500° C.

The system was pumped by a 45 ℓ/s Varian Star Cell pump, and by a 30 ℓ/s Varian diode pump which had a thin aperture in its inlet port to provide a calculated conductance of 5 ℓ/s. In addition, when NEG samples were activated, they had a calculated pumping speed of about 3 ℓ/s. The system was roughed by a cryosorb pump and was baked at 250° C into a water-cooled Hi–Q pump located outside the oven walls. Midway during the cool-down portion of the bakeout, the Star Cell and diode pumps were turned on, and the Hi–Q pump was valved off with an all metal valve.

The system pressure could be measured by (1) a trigger discharge gauge, (2) a nude Bayard–Alpert gauge, (3) a small Faraday plate quadrupole residual gas analyzer, and (4) the current in the 30 ℓ/s pump and 5 ℓ/s conductance combination. The leakage current in the Star Cell pump was always too great and too unstable after bakeout to permit meaningful pressure measurements from its pump current. Typical post bakeout pressures were 10^{-10} Torr with the electron gun filament turned off. All measurements reported here used the Bayard–Alpert gauge for total pressure measurement, and the quadrupole analyzer for partial pressure measurement.

Early in the operation of the system, it was found that secondaries and scattered electrons struck the ceramic insulator, ultimately leading to breakdown. This problem was eliminated by the addition of a pair of electrically isolated baffles surrounding the sample tube, and nearly completely blocking line-of-sight access to the surface of the insulator. Appropriate biases to these baffles prevented most of the scattered electrons from reaching the vicinity of the insulator, and collected the small number which did reach this region.

The samples used were either vacuum degassed Hitachi OFHC copper or OFHC copper to which a nominal 25 micron thick layer of ST707 NEG material had been applied.[3] The application of the getter material was done by SAES Getters on samples supplied by SLAC.

The sample was biased at 5 kV for these tests, and the operating current was about 2.5 mA. These values give a power density on the sample similar to that expected in the SLAC proof-of-principle Lasertron collector, and the relatively low voltage gives a reasonably high gas desorption. The majority of the electrons to be collected in the Lasertron will have energies greater than this value, for which the desorption is somewhat smaller.

4. Method and Analysis

The total desorption rate of CO and CO_2 was determined in two ways. The first is based on the change in pressure when the beam is switched on and off. If the pumping speed is constant, then the electron induced gas desorption rate Q is

*Work supported by the Department of Energy, contract DE–AC03–76SF00515.

Contributed to the Stanford Linear Accelerator Conference, Stanford, California, June 2-6, 1986

$$Q = S\Delta P \quad ,$$

where S is the pumping speed and ΔP is the difference in pressure between the beam on and beam off conditions. A Q of 1 Torr–liter/sec corresponds to 3.5×10^{19} molecules per second. According to the manufacturer, the Star Cell pump has an essentially constant pumping speed over the range of pressure during the measurement (3×10^{-10} to 5×10^{-9} Torr), which for air is 30 ℓ/s. The 5 ℓ/s conductance limited diode pump provided additional pressure measurement independent pumping speed. It was assumed that the pressure everywhere in the vessel was constant, though in fact a pressure variation of a factor of two would not be surprising.

The second method for determining the total desorption rate is based on measuring the difference in the rate of change of the pressure with time between beam on and beam off conditions.[4] In this method,

$$Q = \left(\dot{P}_{\text{on}} - \dot{P}_{\text{off}}\right) V \,/\, kT \quad ,$$

where V is the system volume, $\dot{P}_{\text{on}}$ is the time derivative of the pressure (or partial pressure if desorption of only one species is to be measured) just before the beam is turned off, and $\dot{P}_{\text{off}}$ is the time derivative of the pressure just after the beam is turned off. $\dot{P}$ is measured by sending the signal from the quadrupole analyzer, tuned to a particular mass peak, to a differentiator and then to a chart recorder. The peak (negative) value of $\dot{P}$ is assumed to be $\dot{P}_{\text{off}}$. In practice $|\dot{P}_{\text{on}}| \ll |\dot{P}_{\text{off}}|$ and is taken to be zero. Here, 1 Torr–liter/sec at 300° K gives 3.2×10^{19} molecules/sec.

Considerable care was exercised to attain nearly identical conditions between runs for different collector materials. The electron gun was allowed to warm up overnight with the emission current suppressed. The beam cycle of 2.5 mA on for 120 seconds, followed by beam off for 120 seconds was automatically controlled. The variation in beam current over a run of 24 to 48 hour duration was within ±15%. Nevertheless the total background pressure varied by as much as a factor of three between runs. Two samples of NEG coated material and two samples of vacuum degassed Hitachi OFHC copper were measured, and gave essentially the same results.

As shown in Figs. 1 and 2, both methods of analysis gave similar values for the desorption coefficient (molecules desorbed per incident electron). Because of noise and small signal size, the sensitivity of the $\dot{P}$ method was inadequate to measure the CO_2 desorption rate from NEG coated copper. No error bars are included in the plots for clarity, but an estimated random error of about ±10% per data point, and an overall systematic uncertainty of a factor of two due to possible variations of pressure and pumping speed in the chamber should be understood. Of course, the random uncertainty increases rapidly near the detection limit of about 5×10^{-6} molecules per electron.

When the beam is first turned on the CO_2 (CO) desorption ratio is a factor of 20 (10) less for NEG coated material than for the vacuum degassed OFHC copper sample. At 1000 mA-minutes of exposure the ratio for CO_2 is unchanged, but the ratio for CO has dropped to four. As the exposure increases and the target area becomes more depleted of adsorbed gas, a greater share of the measured desorption rate comes from molecules desorbed from nearby surfaces by backscattered electrons, so the ratio should tend toward one. This may be evident in the CO data, but is not apparent in the CO_2 data.

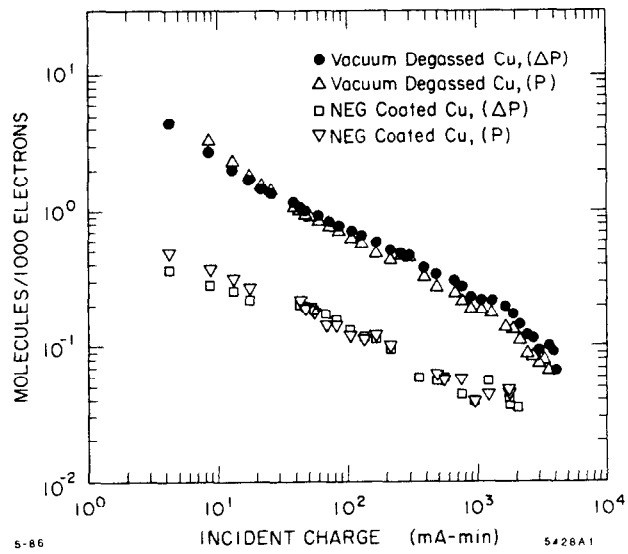

Fig. 1. The total desorption coefficient of CO for vacuum degassed Hitachi OFHC copper and copper coated with about 25 microns of nonevaporable getter material (NEG).

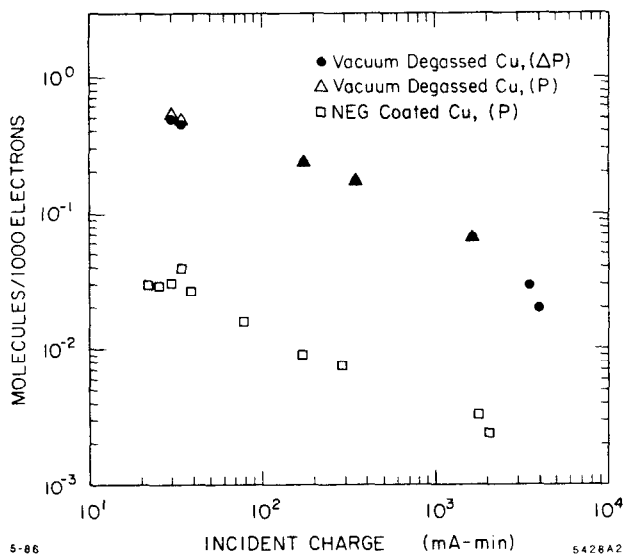

Fig. 2. The total desorption coefficient of CO_2 for vacuum degassed Hitachi OFHC copper and copper coated with about 25 microns of nonevaporable getter material (NEG).

These data show the superiority of the NEG surface over vacuum degassed OFHC copper in minimizing the desorption of CO and CO_2 by electron bombardment. We suggest two possible explanations. One is that the binding of molecules to the NEG surface is stronger than to the copper surface. The other is that there are fewer adsorbed molecules present on the NEG surface, as they tend to diffuse into the bulk even at room temperature. If the latter case is true, then at higher temperatures the desorption rate may be even smaller for the NEG material.

The 25 micron thick NEG coating is thin enough that it offers negligible thermal resistance. Though there may be a small amount of particulation, the surface adheres well at a

power density of about 50 W/cm^2. The NEG coating may be applied to the inside of various cylindrical structures. The exposures delivered in these experiments correspond to abut 6000 hours of full power operation of the SLAC proof-of-principle Lasertron. It appears that the NEG coating is suitable for collector coatings for high current, high power microwave tubes.

References

1. E. L. Garwin, private communication
2. E. L. Garwin *et al.*, *IEEE Trans. Nucl. Sci.* **NS–32**, 2906 (1985).
3. The coating is manufactured, and applied to our samples, by SAES Getters.
4. E. L. Garwin *et al.*, *Proc. Fourth Int. Vac. Congress, 1968*, p. 131.